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Population and plant growth studies of six species of *Eremophila* (Myoporaceae) from central Western Australia

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Abstract

Growth of six *Eremophila* (Myoporaceae) species occurring in central Western Australia were investigated over a period of three years. Field studies at Mt Keith Station (Wiluna) and Mt Weld Station (Laverton) indicated that *Eremophila* showed both germination and growth responses after heavy rainfalls. *Eremophila spectabilis brevis* increased in number from 2407 to 17684 plants ha^{-1} after a one in fifteen year rainfall event. *Eremophila fraserii galeata* increased from 2650 to 9640 plants ha^{-1} in the same period. The other species monitored, *E. exilifolia*, *E. forrestii*, *E. latrobei latrobei* and *E. margarethae*, also showed significant population increases. *Eremophila* germination strategies included generation of multiple seedlings as well as staggered germination from the same fruit over a one year period. Seedling survival was as high as 72% for *E. latrobei latrobei* after one year and seedlings reached a mean height of 8.3 cm in this period. Adult plants increased in height and leaf cover even during adverse seasons. A study of the seed bank of an *E. fraseri galeata* community revealed a mean of 56 fruits m^{-2} under shrubs compared to 2 fruits m^{-2} in bare ground.

Introduction

Eremophila species (Myoporaceae) are hardy perennial shrubs and small trees which occur throughout the arid and semi-arid regions of Australia (Chinnock 1981, 1986), and currently number over 315 species and subspecies (Chinnock *pers. comm.*). The main centre of diversity is the Austin phytogeographic region of Western Australia (Beard 1980). Since many species are tolerant to drought, fire, frost, salinity and grazing, interest in this genus is centred on its potential in rangeland revegetation and minesite rehabilitation programmes (Richmond & Ghisalberti 1994a). There have been number of studies on the taxonomy and biology of *Eremophila* (Beard 1965; Barlow 1971; Bowen 1975; Smith 1975) and their propagation potential (Lothian & Holliday 1964; Beard 1968; Wrigley & Fagg 1979). A detailed examination of the reproductive biology, vegetative and floral morphology of *Eremophila* has also been reported (Chinnock 1982).

Knowledge of the population dynamics of species of this genus is limited. Fruit production and germination in *E. gilesii* and *E. mitchellii* were most noted after rains (>40 mm) during the winter months, March-September (Burrows 1971, 1972; Beeston & Webb 1977). Seed bank studies of *E. gilesii* have demonstrated that the soil can contain more than 400 fruits m^{-2}. *Eremophila spectabilis* increased to 700 plants ha^{-1} yr^{-1} in a grazed paddock during a wet period in 1973-76, and decreased to 116 plants ha^{-1} yr^{-1} during a drought period in 1979-82 (Gardiner 1986a,b). *Eremophila delisseri* and *E. maculata* responded favourably to grazing pressure while *E. forrestii* declined in numbers (Hacker 1987). This study describes plant density, seedling recruitment, survival and growth habits of six species in the Laverton and Wiluna areas of WA over a period of three years.

Methods

The sites selected were at Mt Keith Station (27°17'S, 120°31'E) and Mt Weld Station (28°38'S, 122°24'E) in central Western Australia. An initial survey showed that these sites contain a wide range of *Eremophila* species. From the Mt Weld site, two species were selected for detailed study; *E. forrestii* (MWS1) and *E. margarethae* (MWS3) which are co-dominant species throughout the area located within populations of *Atriplex* (saltbush) and *Maireana* (bluebush) species. From the Mt Keith site, five species were chosen; *E. exilifolia* F. Muell. (MKS1), *E. forrestii* (MKS2), *E. fraseri galeata* Chinnock (MKS3), *E. latrobei latrobei* F. Muell. (MKS4) and *E. spectabilis brevis* Chinnock (MKS5). *Eremophila fraseri galeata* dominates the understorey throughout this area, with *E. spectabilis brevis* as a sub-dominant species. The other three species occur at lower densities and are scattered throughout the region (Speck 1963). General details of the location of the selected species and asssociated flora are given in Table 1. Adult plant density, seedling recruitment, survivorship, and growth habits were evaluated for each species. The data were collected over the period September 1990-June 1993

Assessment of seasonal plant growth period

The climate of the two study areas can be described as arid. The average rainfall at Mt Keith and Mt Weld is 218 and 221 mm respectively. Winter rainfall at Mt Keith is due to the passage of westerly frontal systems, while tropical cyclones and thunderstorms account for the precipitation during the summer months. Average monthly rainfall ranges between 4 mm in September to 37 mm in

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Table 1

Location and description of selected *Eremophila* species at the two study sites.

Species	Location	Description	Associated flora
Mt Weld Station Site	30 km west of Laverton 28°38'S, 122°24'E		
E. forrestii (MWS 1) (Wilcox bush)	Jubilee paddock 28°58'96S, 122°27'22"E	shrub to 2 m, hairy branches, obovate-oblong leaves, tubular flowers	*Acacia aneura, E. latrobei, Templetonia egena, Maireana triptera, Leichardia australis*
E. margarethae (MWS3) (Sandbank Poverty bush)	Brook paddock 28°52'75"S, 122°25'04"E	gray shrub to 1 m, narrowly linear leaves, mauve flowers	*A. aneura, M. triptera, Atriplex nummularia, Ptilotus obovatus*
Mt Keith Site	90 km south of Wiluna 27°17'S, 120°31'E		
E. exilifolia (MKS1)	Jumps Up paddock 27°16'51"S, 120°27'16"E	shrub to 2 m, resinous branches, pink-violet tubular flowers	*A. aneura-A. linopylla, E. latrobei, Calytrix glaucophylla, P. obovatus*
E. forrestii (MKS2) (Wilcox bush)	Red paddock 27°18'96"S, 120°33'56"E	shrub to 2 m, ovate to oblong leaves, pale pink flowers	*A. aneura, E. latrobei, P. obovatus, Cassia* sp.
E. fraserii galeata (MKS3) (Turpentine bush)	Rocky Hills paddock 26°10'82"S, 120°36'20"E	shrub to 3 m, resinous leaves, ovate leaves, red tubular flowers	*A. aneura, Cassia* sp.
E. latrobei latrobei (MKS4) (Warty fuchsia bush)	Red paddock 27°19'01"S, 120°33'54"E	gray, green shrub to 2.5m, warty branches, linear-oblong leaves	*A. aneura, P. obovatus, Cassia* sp., *Triodia basedowii*
E. spectabilis brevis (MKS5) (Showy poverty bush)	Two Tanks paddock 27°13'98"S, 120°36'84"E	shrub to 2 m, resinous branches, linear-lanceolate leaves, purple flowers, dark grey bark	*A. aneura, E. foliosissima, Eragrostis eriopoda, Prosantha* sp.

March. The highest mean maximum monthly temperature was 37.7 °C in January, and the lowest mean minimum monthly temperature was 5.3 °C in July (Bureau of Meteorology, Perth); evaporation exceeds 5440 mm yr^{-1}. As a consequence of episodic rainfall and high evaporation rates, short growing seasons and frequent droughts are characteristic. Rainfall at Mt Weld is more dependable during the late summer with precipitation being brought about by cyclonic activity. Average monthly rainfall ranges between 7 mm in October to 31 mm in March. The highest mean maximum monthly temperature was 35.9 °C in January, and the lowest mean monthly minimum temperature was 5.2 °C in July; evaporation exceeds 3473 mm yr^{-1} (Beard 1974).

Study site design and assessment

Circular study plots (diameter 25 m) were partitioned into 30° sectors in which the exact location of individual plants could be monitored (Lindsey *et al.* 1958; Mueller-Dombois & Ellenberg 1974). The MKS study sites were visited four times a year in the first year (1991), but this was reduced to two per year (December and June) in

Table 2

Monthly rainfall (mm) for the period 1989-1993 recorded at Mt Keith (Mt Keith Station Exploration Camp, Western Mining Corporation) and Mt Weld station (Granny Smith Gold Mine, Placer Pacific Ltd).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mt Keith station													
1989	9.5	31.0	32.5	32.5	13.5	44.0	0.0	0.0	0.0	0.0	13.2	0.0	173.7
1990	100.8	18.3	7.8	1.4	9.2	6.2	12.7	26.5	1.8	1.6	1.0	0.0	187.3
1991	0.0	0.0	14.0	8.1	0.0	33.5	22.6	0.0	5.0	0.0	0.0	8.8	92.0
1992	20.3	5.6	75.6	126.4	16.8	32.2	0.0	29.8	40.4	0.0	4.2	0.9	398.7
1993	0.0	62.0	7.8	41.0	37.2	35.0	-	-	-	-	-	-	
Mt Weld station													
1989	4.4	0.0	0.0	23.0	40.6	29.8	0.0	0.0	0.0	0.0	19.6	2.2	119.4
1990	79.6	2.4	0.0	24.0	21.6	11.8	33.4	343.7	0.3	29.4	0.2	12.1	248.5
1991	0.4	0.0	3.5	25.5	52.0	37.7	12.8	0.8	2.8	7.0	0.5	40.6	183.6
1992	13.5	56.5	64.4	102.7	47.1	29.6	3.2	99.4	46.1	13.5	3.5	1.5	481.0
1993	0.1	20.5	36.0	28.2	100.2	43.7	-	-	-	-	-	-	

1992 and 1993 due to minimal seedling establishment and unfavourable seasonal conditions. The MWS study sites were visited twice per year. All study sites (excluding MKS1 in breakaway country) were fenced to reduce the impact of sheep and kangaroos.

Plant height (H), widest point (W_1) and perpendicular (W_2) width were measured and categorised into two groups. The inverted cone shape described *E. exilifolia*, *E. latrobei latrobei* and *E. spectabilis brevis*, and canopy volume was calculated using the geometric formula ($^{\pi}/_{3}\ r^2h$) (Ludwig *et al.* 1975). The upper half spheroid form (Witkowski *et al.* 1991), $^{4}/_{3}\ \pi\ (W_1/2)\ (W_2/2)\ (H/2)$, was used for *E. fraseri galeata*, *E. forrestii* and *E. margarethae*. Changes in mean shrub height (cm) and canopy volume (m^3) between summer 1990 and winter 1993 were calculated and tested using a one-way ANOVA. Differences between means were contrasted using Scheffe's test.

Germination and seedling establishment

Newly established seedlings were counted on each visit, tagged, labelled and the heights measured. The number of seedlings produced per fruit was individually assessed. The proportion of seedling which had germinated during the winter of 1992 and survived into winter 1993 was assessed.

Seed bank variation of *E. fraseri galeata* (MKS3)

The seed bank variation for an *E. fraseri galeata* community was investigated during December 1992. Thirty adult shrubs within the height range of 1.5-2.0 m were selected adjacent to MSK3. A further 30 sites, each situated 3 m from the selected shrubs within a bare scalded area, were chosen at random for seed-bank sampling. Since the shrub canopy of this species overhangs the main stem with a radius of approximately 0.5 m, a 1 m soil pit (depth 10 cm) immediately around the central stem was selected. Soil and litter fractions were separated, bagged, and taken to the laboratory for sieving. The soil was sieved using an automated sieve (aperture 140 mm, mesh size 2.5 mm (No.14), diameter 21.5 cm). This fraction was further sieved by hand (wooden sieve, diameter 48.5 cm, mesh size 2.0 mm) for fruit collection.

A statistical comparison of the fruit bank number between the combined soil and litter fraction in vegetated and non-vegetated sites were assessed using a t-test. An evaluation of fruit density within the two litter and soil fractions from the bare ground and under *E. fraseri galeata* shrubs were assessed using a Duncan's Multiple Comparison Test.

Results

Although germination occurred for a number of species during the winter and summer of 1991, these values were minimal and are not discussed in detail. Plant growth and seedling establishment occurred after favourable rainfall events during winter 1992 (Table 1). Mt Keith received 400 mm (twice the yearly average), a situation that has occurred only on eight occasions over the last 100 years. Mt Weld received 480 mm, the highest recorded rainfall since records began in 1900 (Table 2).

Table 3

Shrub community density, recruitment and mortality of *Eremophila* species at the Mt Keith (MKS) and Mt Weld sites (MWS); Su = summer, Au = autumn, Wi = winter, Sp = spring. Seedling survived refers to those seedling that had germinated in previous seasons and were still surviving at the time of the observation

Season	Shrub number per plot			
	adults	seedlings		
		germinated	survived	dead
E. exilifolia (MKS1)				
Su90	73	0	-	-
Au91	73	0	0	0
Wi91	73	0	0	0
Sp91	72	1	0	0
Su91	72	0	1	0
Wi92	69	98	1	0
Su92	64	63	86	12
Wi93	64	21	80	69
E. forrestii (MKS2)				
Su90	32	0	-	-
Au91	32	0	0	0
Wi91	31	0	0	0
Sp91	31	0	0	0
Su91	31	0	0	0
Wi92	19	32	0	0
Su92	17	17	32	0
Wi93	17	14	49	18
E. fraseri galeata (MKS3)				
Su90	132	0	-	-
Au91	132	0	0	0
Wi91	131	0	0	0
Sp91	130	0	0	0
Su91	130	0	0	0
Wi92	122	148	0	0
Su92	115	237	121	27
Wi93	108	11	183	175
E. latrobei latrobei (MKS4)				
Su90	42	0	-	-
Au91	42	0	0	0
Wi91	42	0	0	0
Sp91	42	0	0	0
Su91	42	2	0	0
Wi92	33	108	2	0
Su92	33	145	100	8
Wi93	31	33	66	79
E. spectabilis brevis (MKS5)				
Su90	118	0	-	-
Au91	118	0	0	0
Wi91	118	0	0	0
Sp91	118	0	0	0
Su91	118	0	0	0
Wi92	111	756	0	0
Su92	110	34	625	131
Wi93	109	16	349	310
E. forrestii (MWS1)				
Su90	31	0	-	-
Wi91	31	2	0	0
Su91	31	1	2	0
Wi92	28	27	0	3
Su92	28	42	27	0
Wi93	28	3	42	27
E. margarethae (MWS3)				
Su90	42	0	-	-
Wi91	42	4	0	0
Su91	42	0	2	2
Wi92	38	13	0	2
Su92	38	13	13	0
Wi93	38	0	12	14

***Eremophila exilifolia* (MKS1).** The adult plant density was 73 plants in 1991 (Table 3). Following significant rainfall (103 mm) in winter 1992, seedling recruitment was high (98 seedlings), increasing the population to 213, and this was largely maintained into winter 1993 (165 plants). Between winter and summer 1992, a period with little rain, adult plant mortality was 5. The majority of fruits produced individual seedlings during the period winter 1992-winter 1993, consisting of 87, 89 and 100% of total fruit recruitment. Twin seedlings were recorded during the winter and summer of 1992, and comprised 10% and 8% of total seedling production. All fruits with multiple seedlings (twins to quadruplets), which survived for one year, lost seedlings and had become individual seedlings by the winter of 1993.

***Eremophila forrestii* (MKS2).** The population of 32 adult plants during 1990 at Mt Keith declined marginally to 31 plants by summer 1991 (Table 3). During the first half of 1992, the adult population was reduced to 19 plants. However, this trend was offset by favourable rains of March (76 mm) and April 1992 (126 mm). When the 32 new seedlings were examined, all the fruits were found to produce individual seedlings. New germinants were also recorded during summer 1992 (63 seedlings) and winter 1993 (14 seedlings). The total population of 31 plants in summer 1991 had risen to 80 in winter 1993.

***E. fraseri galeata* (MKS3).** This shrub community was characterised by two age cohorts, four adult "mother" plants (average height 1.8 m) and 128 young shrubs (average height 16 cm), estimated to be 4-5 years old. The adult community appeared stable, with a gradual decline in numbers from 132 to 108 plants from summer 1990 to winter 1993 (Table 2). This decline was compensated by a marked germination event of 148 seedlings during winter 1992. These germinants were clustered around the "mother" plants and were characterised primarily by individual seedlings per fruit (103 individuals; 70% of total germinants). However, twin (24%), triplet (5%) and quadruplet germinants (1%) were also recorded. Germination was observed in summer 1992 when 237 germinants emerged. While the majority of multiple seedlings were reduced in number, primarily to individual seedlings per fruit, some fruits which initially were individual seedlings continued to produce more seedlings. For example, of the 78 single seedlings which germinated in winter 1992 and survived during the summer of 1992, five were recorded as twins while one individual fruit produced triplet seedlings. In the area containing the majority of germinants, shade, nutrients and cover from annuals, *e.g. Aristida arenaria*, *Eragrostis dielsii*, *Eriachne pulchella* and *Calandrinia* species, were abundant.

***Eremophila latrobei latrobei* (MKS4).** The plant community of 42 plants remained stable from summer 1990 to summer 1991 (Table 3). A marked decline in adult numbers (33 plants) occurred during winter 1992 and into winter 1993 (31 plants). However, this pattern of adult mortality was compensated by recruitment of 108 and 145 germinants during winter and summer 1992. The majority of germinants comprised individual seedlings though multiple germinants were recorded, ranging from twins to quintuplet (one) fruits. In terms of total shrub density, this community peaked at 278 plants during summer 1992, but declined to 130 plants during winter 1993, a decline due primarily to seedling mortalities (44% loss).

***Eremophila spectabilis brevis* (MKS5).** The adult population remained stable at a density of 118 plants from summer 1990 to summer 1991, declining slightly to 111 plants by winter 1993 (Table 3). Germination following favourable early winter rains during 1992 offset this decline and 756 seedlings was recorded. High survival rates (83%) of these seedlings during the summer 1992 period with the addition of a further 34 germinants, resulted in a population increase to 769 plants. However, by winter 1993 only 349 seedlings (53%) survived. The majority of fruits produced individual seedlings (98, 91 and 94% for the winter, summer 1992 and winter 1993 respectively) and the remaining germinants were twins and triplets.

Table 4

Mean shrub height and canopy volume for *Eremophila* species between summer 1990 and winter 1993 at Mt Keith and Mt Weld stations. Means between species with the same letters do not differ significantly ($p<0.05$) by Scheffe's test. Values are mean with the standard error in parentheses.

Site	MKS1	MKS2	MKS3	MKS4	MKS5	MWS1	MWS3
Species subspecies	*E. exilifolia*	*E. forrestii*	*E. fraseri* *galeata*	*E. latrobei* *latrobei*	*E. spectabilis* *brevis*	*E. forrestii*	*E. margarethae*
Sample size (n)	67	17	108	30	108	28	4
				Mean shrub height (cm)			
Summer 1990	78.13 (5.23)	55.06 (9.40)	24.51 (3.21)	155.93 (10.29)	54.40 (1.86)	77.89 (7.13)	62.91 (2.81)
Winter 1993	85.96 (5.18)	58.70 (10.16)	31.88 (3.26)	156.50 (10.03)	58.85 (1.79)	81.57 (6.10)	69.14 (2.11)
Mean	82.04 (3.91)^{a}	56.88 (1.82)^{b}	28.20 (3.86)^{c}	156.21 (0.28)^{d}	56.47 (1.57)^{b}	79.73 (1.84)^{a}	66.02 (3.11)^{e}
				Mean shrub canopy volume (m^3)			
Summer 1990	0.44 (0.08)	1.24 (0.51)	0.36 (0.17)	0.48 (0.10)	0.07 (0.01)	1.76 (0.36)	0.46 (0.09)
Winter 1993	0.56 (0.09)	1.42 (0.54)	0.45 (0.21)	0.61 (0.10)	0.11 (0.01)	1.94 (0.38)	0.60 (0.09)
Mean	0.50 (0.06)^{a}	1.33 (0.09)^{b}	0.40 (0.04)^{a}	0.54 (0.06)^{ac}	0.09 (0.02)^{d}	1.85 (0.09)^{e}	0.53 (0.07)^{ac}

***Eremophila forrestii* (MWS1).** A similar trend was observed at Mt Weld station with the most significant germination event occuring after the winter rain of 1992. Following this period, a total of 27, 69 and 45 seedlings were recorded to winter 1993 (Table 3). The majority of new germinants were noted to be single seedlings.

***Eremophila margarethae* (MWS3).** The adult plant density remained relatively stable (42 to 38 plants) from winter 1991 to 1993 (Table 3). Germination peaked in the winter and summer 1992, but was followed by a seedling mortality of 54% between winter 1992 and winter 1993.

Mean shrub height and canopy volume

The smallest mean shrub height was 28.20 ± 3.68 cm (n=108) for *E. fraseri galeata* and the largest shrub height was recorded for *E. latrobei latrobei* with 156.2 ± 0.3 cm (n=30; Table 4). In terms of canopy volume, *E. spectabilis brevis* and *E. forrestii* (MWS3; MKS2) had the lowest and highest canopy volume, 0.09 and 1.85 (1.33) m^3 respectively. The remaining species were closely related with a range of 0.40 - 0.54 m^3 (Table 4).

Germination and seedling establishment

The survival rates of all single seedlings which germinated during the winter period of 1992 was observed for 1 year (Table 5). One year after seedling establishment, 60, 69 and 30% respectively of the seedlings of *E. forrestii* (MWS1; MKS2) and *E. margarethae* (MWS3) survived. All the other species followed a constant mortality rate. The greatest proportion of mortalities was related to the species which produced the highest number of germinants; *E. exilifolia, E. fraseri galeata, E. latrobei latrobei* and *E. spectabilis brevis.*

Seed bank variation for an *E. fraseri galeata* community

The number of fruits in bare ground (2.2 ± 0.4) and under an *E. fraseri galeata* canopy layer (56.0 ± 16.4) was significantly different ($p<0.01$). There was also a significant difference ($p<0.05$) in fruit numbers under the plant within the soil (42.9 ± 14.3) and litter zones (13.1 ± 3.4) compared to the non-vegetated soil (1.3 ± 0.3) and litter zone (0.9 ± 0.2). If the adult population density of 4 "mother" plants is extrapolated to 81 adults ha^{-1}, with each plant possessing a mean of 56 fruits per plant, the estimated total is 4536 fruits ha^{-1}. Assuming the remaining area consists of either bare ground or *E. fraseri galeata* community other than "mother" plants, the estimated fruit count is 21822. Since each fruit may contain up to 8 seeds, the maximum potential is 210864 seeds ha^{1}. The mean litter weight under the canopy was estimated as 5328 kg ha^{-1}, in contrast to 2693 kg ha^{-1} for the bare areas.

Table 5

Proportion of seedlings surviving over 12 months (Wi = winter, Su = summer)

Species	Site	Wi92	Su92	Wi93
E. exilifolia	MKS1	1.00	0.75	0.42
E. forrestii	MKS2	1.00	1.00	0.69
E. fraserii galeata	MKS3	1.00	0.76	0.49
E. latrobei latrobei	MKS4	1.00	0.93	0.72
E. spectabilis brevis	MKS5	1.00	0.83	0.46
E. forrestii	MWS1	1.00	1.00	0.60
E. margarethae	MWS3	1.00	1.00	0.30

Discussion

Eremophila species are well adapted to arid conditions, some capable of surviving without any rainfall for approximately 2 years (Elliot & Jones 1984). Adult shrub mortalities were recorded at all sites in the seasons 1990-1991, probably due to lack of rain. Favourable rainfall events at both sites during autumn and winter of 1992 resulted in significant levels of seedling recruitment for all species. The density of germinants at Mt Weld was markedly lower than at Mt Keith. This may be due to the competitive effect of *Atriplex* and *Maireana* species which dominated as an understorey species at the former site. At Mt Keith, with the exception of scattered communities of *Eragrostis erapoda* and *Triodia basedowii*, the understorey consists primarily of *Eremophila* species.

Following the high rainfall of winter 1992, the *E. spectabilis brevis* (MKS5) community (15420 germinants ha^{-1}) increased to a shrub population of 17684 ha^{-1}. All fruits which produced seedlings appeared to be highly weathered, indicating that they were several years old. This, combined with the rain which leaches out germination inhibitors in the fruit wall (Richmond 1993; Richmond & Ghisalberti 1994b), might explain the high recruitment rate. *E. spectabilis brevis* appears to be a highly competitive and aggressive species when favourable seasonal conditions occur (Richmond 1993). The fruits can contain up to 12 seeds compared to a maximum of eight for the other species under investigation. This may be a contributing factor to the higher germination rate. Its seedling recruitment pattern resembles that of the Queensland species *E. gilesii*, to which it is taxonomically closely related (Section Eremaeae; Chinnock *pers. comm.*). Many seedlings appeared from one fruit, illustrating the highly competitive nature of this species.

While most germination involved fruits possessing single seedlings, some fruits produced multiple seedlings, with quintuplets being recorded for fruits of *E. fraseri galeata* during the summer of 1992. Burrows (1971) also observed multiple seedlings (11.8% twin and 2.5% triplets) produced from fruits of *E. gilesii* after a 40 mm rainfall event. An interesting observation in the present study is that, when climatic variables are favourable, the fruits may continue to produce multiple germinants several months after initial germination.

Seedlings of *E. forrestii* (MKS2 and MWS1), *E. latrobei latrobei* (MKS4) and *E. margarethae* (MWS3) appear resilient to desiccation, since 100, 93 and 100% survived 6 months after germination. Field observations suggested that their survival may be due to a characteristic thickening of the hypocotyl and rapid root establishment. These hypocotyls were hirsute, thus possibly reflecting damaging light and reducing evapo-transpiration (Clifford 1987). *Eremophila forrestii* and *E. latrobei latrobei* appeared to have the fastest growth rates in terms of height gained over 1 year, with a mean of 8.3 cm, compared to 5.9 cm for the remaining species.

Whilst germination was observed for all species within the study sites, seedling survival was characterised by an aggregation around old plant remains and under canopies of existing shrubs and small trees. Within the *E. fraseri galeata* community, germinants aggregated within the canopy drip line of adult plants as noted by Hacker (1984). Increased accumulation of nutrients, water availability and soil depth beneath adult plants may contribute towards the establishment and maintenance of *E. forrestii* within the arid shrublands (Hacker 1979, 1984).

A study of the seed bank variation within the soil and litter layer of an *E. fraseri galeata* community revealed a mean concentration of 56 fruits m^{-2} under each shrub compared to 2 fruits m^{-2} in bare ground. This highlights the point that the litter and detritus layers may play a role in maintaining favourable edaphic factors and microclimate, thereby promoting seedling germination and survival when better environmental conditions occur (Hacker 1984). The total fruit count was 26402 fruits ha^{-1} and is an important topsoil seed bank for this community. The fruit bank for *E. gilesii* is far greater, with 4285000 ha^{-1} being calculated by Burrows (1971) for a plant community comprising 60000 adults ha^{-1}. It is interesting to note that *E. gilesii* is a prolific seeder with a life span of approximately 10 years (Burrows 1974), whereas *E. fraserii* has a life span of 100 years (Chinnock 1974). For *E. sturtii* and *E. mitchellii*, 170000 fruits ha^{-1} have been recorded (Hodgkinson *et al.* 1980).

Germination and growth of *Eremophila* species occur on relatively impoverished soils when favourable conditions occur. This has been illustrated by the large increase in population of *E. spectabilis brevis* after high rainfall, and is indicative of the ability of this genus to regenerate at high levels. A species' ability to survive both in time and space is associated and enhanced by the germination characteristics, particular if multiple seedlings emerge from one fruit.

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